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INTRODUCTION

To test the effectiveness of various reclamation treatments upon the poor physical condition of a saline-alkali soil on the Safford Experimental Farm, a number of chemical, irrigation, and tillage experiments have been conducted with various degrees of success. A recent approach to the problem has been the rather unique one of passing a rectified electrical current through the soil, the objective being the removal of excess soluble salts, particularly the sodium salts, and to improve crop production. The claim is made by advocates of this method that the electrical process speeds the leaching of the excess salts from the root-zone as a result of chemical and physical changes produced by the current. They also claim that migration of ions does occur, and that water and colloids move toward one or the other electrode in a small area of wet soil, say a few feet between electrodes.

"Demonstrations" have been set up recently in Arizona and California on a number of farms. They have attracted the attention of farmers and those interested in reclamation problems. Most of the installations have employed a 115-volt single-phase AC rectifier delivering from 30 to 40 volts of direct current, at up to 50 amperes when the soil moisture conditions are favorable. Much less current is delivered under normal cropping conditions. A line of cathodes driven to about 10 feet at one end and a corresponding line of anodes driven to about 2 or 3 feet at the other end, "treat" an area of approximately 10 acres, the distance between lines being about 1,000 to 1,200 feet.

As a result of this interest in a new process of unproven value, an experiment was planned to learn something of the actual effectiveness of the treatment.

EXPERIMENTAL METHOD

Electrical Arrangement: Such a process as this is dependent upon the conduction of electrical current through the soil in an unpredictable pattern. Thus it is practically impossible to set up a randomized, replicated design, since the current cannot be stopped by borders between plots. In fact, an induction current was found to be flowing in the buffer plots in the opposite direction to that in the treated plots. The present experiment was laid out as shown in Figure 1, with four treated plots, two checks, and buffer plots between test plots. Each plot measured 0.139 acre. Soil samples were collected on February 28, 1956 when the experiment was laid out at 1, 2, and 3 foot depths, 8 feet toward the center from each electrode, and across the center of each treated and check plot. The evaluation of this experiment depended largely upon differences found between these samples and another set taken after a period of treatment in the same spots under as similar conditions as possible, and upon harvest data of the test crop.

Two cathodes ($6\frac{1}{2}$ foot steel fence posts from which the paint had been removed) were driven to 6 feet at the west ends of the treated plots, see Figure 1. They were connected by #9 soft aluminum tie wire, and the aluminum wire to the rectifier negative pole by #6 insulated copper wire. About 230 feet away, the anodes (3 inch extra-heavy steel pipes) were driven 2 feet into the soil. The anodes were connected by aluminum wire. Copper wire was used to connect the anodes to the rectifier positive pole. The transformer-rectifier, with 3-phase 220 volt AC input, has an adjustable output of up to 40 volts direct current at about 35 amperes when the soil is wet, to as low as 5 amperes when very dry. The installation of the rectifier was not completed until April 18.

Field Plan: Sweet sudan grass seed was broadcast after disking the field. The first irrigation was applied on April 18, when the current was turned on to run continuously at the highest setting. The soil was kept wet by semi-weekly irrigations for 3 weeks, the final irrigation being on May 27, allowing a 3 week wet period during which as large a quantity of current as possible could pass through the soil. The field was then allowed to dry until May 26. The current was maintained continuously during the test period. On May 23 the soil was dry enough to take samples. Ammonium phosphate 16-12-0 fertilizer at 250 pounds per acre was applied, and the plots were re-seeded. The excess moisture of the wet period had caused high mortality of the seedlings. On May 25 another irrigation was applied, and electrical treatment continued until August 13. The sudan was harvested for dry weight on July 29.

Soil Analysis: Soil was sampled for chemical analysis 8 feet from each end of the plot and in the center of the plot. The total soluble salts and the pH of the saturated paste extract were determined by the method recommended by the U. S. Salinity Laboratory Handbook 60 (3). Total cation exchange capacity and exchangeable cations were determined by the procedure suggested in Bower, *et al.* (1) and a second method of Chang and Dregne (2).

RESULTS

Soil: A summary of the results obtained by analysis of the surface foot of soil collected before "electro-reclamation" appears in Table 1. Though the range in salinity varied considerably, the soils are classified as saline. At the anode end of the borders the conductivity of saturation extract ranged from 4.1 to 6.8 mmhos/cm. The plot centers ranged from 4.7 to 10.5 mmhos/cm, whereas the soil at the cathode end ranged from 5.7 to 10.7 mmhos/cm. The soluble calcium in the soil extract varied from 5 to 12 percent over the whole field. The exchangeable-sodium-percentage was generally higher at the east than the west end. This is due primarily to differences in soil texture between the two ends of the borders.

An analysis of the soils at the same location 35 days after "electro-reclamation" and leaching treatment is shown in Table 2. A change in accumulation of soluble salts took place during this period. Salt appeared to accumulate slightly over the whole area except in some samples adjacent to the anode. The water appeared to leave more salts than it removed, even though electric treatment was continually in operation. No statistical significant differences between means of "electro-treated" and untreated plots was found. Sodium accumulated at a faster rate than calcium as a result of using the saline well water available in this area. The saline condition of the soil was modified in no way by the electrical treatment.

There was no evidence of migration of sodium from any part of the "electro-treated" plots toward either of the electrodes. Although the data in Table 3 showing the exchangeable sodium percent appeared to build up slightly at the cathode end of the field, there was no significant difference between the untreated and electrically treated plots. In most instances where leaching appeared to remove salts, more calcium than sodium salts were lost.

Advocates of "electro-reclamation" claim that the soil in the vicinity of the anode turns acid and soil surrounding the cathode is highly alkaline. Too much emphasis has been given to this theoretical possibility. Data in Table 4 show no significant difference in pH value or salt concentration in soil samples taken 1, 2, 3, or 8 feet away from either the anode or cathode poles and to a depth of 3 feet.

The effect of "electro-reclamation" on the yield and appearance of sudan grass also was not measurably significant, Table 5.

<u>Cost of Operation</u>: The cost of "electro-reclamation" from March through August is shown in Table 6. The cost per day decreased as the time of the electrical treatment increased. During the wet period the cost was about $2.00 a day for the four borders of 0.556 A. The total charge for the duration of the experiment of 4 months was $1.118 per day. Much less electricity was used when the soil was dry. During the driest period, June 11 to August 13, 63 days, the cost averaged $0.755 per day. The daily meter readings and corresponding DC amperage is shown in Figure 2 to descrease as the time of reclamation procedure increased. After the middle of July the DC amperage dropped below a value of 10.

<u>Effects of Electrode Corrosion</u>: One of the characteristics of the DC amperage calculations was that during each subsequent irrigation the amount of current output was reduced. There was considerable corrosion on the electrodes. At the conclusion of the experiment, the electrodes were removed and re-set in a study to determine to what extent this corrosion was responsible for this progressive decline in the flow of current.

On border 10, at the west end, 4 cathodes were driven to about 3 feet, 5 feet apart; 50 feet east, 6 anodes were set to a depth of 2 feet, 4 feet apart. Three of the anodes were kept as removed - covered with a coat of corrosion 1/8 inch or more thick. Three were polished to bright metal by use of a wire brush wheel. The cathodes were connected together to the negative pole of the rectifier as before; the 3 polished anodes were connected together separately from the line connecting the corroded anodes, so that readings of the two sets could be made alternately or all together. From the north, the first, third, and fifth anodes were corroded; the second, fourth, and sixth were polished. All were lined up the same distance from the line of cathodes. The soil surrounding each anode was soaked with a bucket of water when the re-installation was completed on Wednesday evening, October 10. No more water was added to the anode sites, but the soil was kept wet around the cathodes. The field was very dry, over a month having elapsed since the last irrigation. On October 10, at 5:00 p.m. the following readings were recorded (all at or near 37 volts).

All 6 electrodes (anodes)	5.00 amperes
3 polished anodes	4.22 "
3 corroded anodes	4.14 "

The current was left on over night, connected to the corroded set of anodes. Later readings were recorded at intervals as stated below:

	Thursday		Friday	
	8 a.m.	noon	5 p.m.	noon
All 6 anodes	6.00 amps.	6.00 amps.	6.00 amps.	6.00 amps.
3 polished anodes	5.04 "	5.03 "	5.07 "	4.70 "
3 corroded anodes	4.12 "	4.27 "	4.27 "	4.08 "

The current was again left on Thursday night connected to all six anodes. At 2 p.m. Friday the anodes were disconnected one at a time with the following results:

	all 6	North 5	North 4	North 3	North 2	First
Amperes	6.0	5.67	5.33	4.78	4.22	3.0

The current flow for each anode individually was then read. The data are recorded in Table 7. All the data are averages of two separate readings using a variable shunt to give the meter more accuracy.

After Wednesday evening the readings of the polished anodes were consistently from 12.5 to 22.6% greater than those of the corroded electrodes. It seems safe to assume that the accumulation of corrosion on the anodes (the cathodes did not corrode) accounts for the progressive drop in current flow through the field during the experiment. It was not caused by removal of salts.

DISCUSSION OF RESULTS AND SUMMARY

The experiment described is an attempt to evaluate a process which is difficult to appraise quantitatively, or to find any evidence to substantiate claims that have been made for it. Chief dependence for evaluation was placed on chemical analyses of the soil in electrically treated and untreated plots sampled at particular spots to a depth of 3 feet before and after a 35 day period in which moisture was maintained at a high level to allow the flow of as large a quantity of direct electrical current as possible. Saline well water was used. The north half of the test area was treated by the addition of gypsum to the irrigation water. Apparently the gypsum so added had negligible effect upon the action of the electrical treatment. The only changes found to have occured can be attributed to the effects of leaching with well water. Electrical treatment did not affect the soil in any of the measurements employed.

Whether any plant growth stimulation by the electrical current may be detected in an experiment of this kind is doubtful. The yield of sudan hay indicated that no increase in the growth of sudan grass resulted from the electrical treatment.

Cost-wise, this treatment returned nothing for the investment in equipment, labor, or the electricity consumed. The experiment was conducted on a total of four plots having 0.139 acre of usable land each, or a total of 0.556 acre. This figure is based upon the disregard of leakage of electricity to adjacent plots. Electricity consumed varied from 1900 to 3200 watts per acre, costing daily from $1.36 to $2.48 per acre. From 700 to 1590 watts of direct current per acre was passed through the soil in this experiment compared with a typical "demonstration" by a private concern, in which 1800 watts of direct current are passed through 10 acres of land, or an average of 180 watts per acre. It should be reasonable to expect that results might have been found by the Experiment Station test in at the most a fourth of the time required as in the large-scale layout. Yet in four months, no measureable results could be detected. One can only conclude from the evidence at hand that "electro-reclamation" at the rate of electrical current recommended is an ineffective, expensive attempt at reclaiming or improving soils.

REFERENCES

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Table 1. Some chemical properties of the soil in the area used for the "electro-reclamation" experiment before electrical treatment - surface 12 inches*.

PLOT NUMBER AND TREAT-MENT	pH VALUE	CONDUCTIVITY OF SATURATION EXTRACT mmhos/cm	Ca OF SAT'N EXTRACT m.e./L	SOLU-BLE Ca percent	EXCHANGEABLE SODIUM PER-CENTAGE percent	SATURATION PERCENTAGE percent
Anode End of Plot						
1 untreated	8.40	6.8	6.1	9	28	43
12 untreated	8.40	4.1	2.3	6	30	45
3 electro-treated	8.42	5.9	4.8	8	30	40
5 electro-treated	8.35	6.8	6.3	9	31	44
8 electro-treated	8.40	4.4	2.8	7	31	45
10 electro-treated	8.50	5.7	2.9	5	33	47
Center of Plot						
1 untreated	8.50	4.9	3.7	8	31	41
12 untreated	8.45	6.7	3.8	6	28	58
3 electro-treated	8.40	8.5	8.8	10	30	40
5 electro-treated	8.45	4.7	3.2	7	30	51
8 electro-treated	8.42	6.1	3.1	5	24	62
10 electro-treated	8.37	10.5	7.3	7	24	63
Cathode End of Plot						
1 untreated	8.37	5.7	4.2	7	24	53
12 untreated	8.35	5.8	3.4	6	26	60
3 electro-treated	8.38	10.7	12.4	12	24	50
5 electro-treated	8.30	8.1	7.1	9	22	60
8 electro-treated	8.45	9.6	7.1	7	26	64
10 electro-treated	8.42	6.8	4.0	6	26	60

L.S.D. at 0.05 level does not approach significance for any chemical property given for soils at either end or center of the plot.

* Figures represent the mean of 6 cores per sample.

Table 2. Some chemical properties of the soil in the area used for the "electro-reclamation" experiment after electricity was impressed through the soil surface 12 inches.*

PLOT NUMBER AND TREATMENT	pH VALUE	CONDUCTIVITY OF SATURATION EXTRACT	CALCIUM OF SATURATION EXTRACT	SOLUBLE CALCIUM	EXCHANGEABLE SODIUM PERCENTAGE
		mmhos/cm	m.e./L	percent	percent
			Anode End of Plot		
1 none	8.40	6.0	4.4	7	30
12 none	8.40	6.2	5.3	6	30
3 electric	8.47	6.4	4.6	7	30
5 electric	8.47	5.7	4.1	7	26
8 electric	8.33	5.0	2.7	5	31
10 electric	8.40	6.2	3.2	5	30
			Center of Plot		
1 none	8.40	5.8	3.6	6	30
12 none	8.43	6.3	3.3	5	26
3 electric	8.43	5.7	3.3	6	30
5 electric	8.40	6.2	3.4	6	26
8 electric	8.38	5.3	3.0	6	26
10 electric	8.43	7.3	3.7	5	26
			Cathode End of Plot		
1 none	8.42	6.2	3.7	7	31
12 none	8.58	9.8	6.5	7	26
3 electric	8.48	8.3	3.7	9	30
5 electric	8.50	7.7	5.7	8	28
8 electric	8.43	8.8	5.2	6	26
10 electric	8.52	5.8	3.1	5	28

L.S.D. at 0.05 level does not approach significance for any chemical property given for soils at either end or center of the plot.

* Figures represent the mean of 6 cores per sample.

Table 3. Exchangeable-sodium-percent in the first and third foot of soil at various locations in the "electro-reclamation" plots before and after treatment with electricity.

PLOT NUMBER AND TREATMENT	1ST FOOT PRE-TREATMENT	1ST FOOT POST-TREATMENT	3RD FOOT PRE-TREATMENT	3RD FOOT POST-TREATMENT
Anode End of Plot				
1 none	28	30	26	26
12 none	30	30	30	26
3 electric	30	30	28	26
5 electric	31	26	26	24
8 electric	31	31	26	31
10 electric	33	30	31	33
Center of Plot				
1 none	31	30	30	30
12 none	28	26	31	31
3 electric	30	30	30	31
5 electric	30	26	31	30
8 electric	24	24	31	31
10 electric	24	26	30	33
Cathode End of Plot				
1 none	24	31	30	36
12 none	26	26	30	35
3 electric	24	30	31	36
5 electric	22	28	30	33
8 electric	26	26	30	34
10 electric	26	28	33	40

Significant difference at the 0.05 level between electric and untreated plots was not found.

Table 4. The influence of "electro-reclamation" on salt content of soil at various depths in the soil and at various distances from the cathode and anode poles*.

MEASUREMENT	DISTANCE FROM ANODE POLE 1 FOOT	2 FOOT	3 FOOT	8 FOOT	DISTANCE FROM CATHODE POLE 1 FOOT	2 FOOT	3 FOOT	8 FOOT
First Foot								
EC_S - mmhos/cm	4.8	5.3	5.3	5.0	4.7	6.7	8.3	8.8
Solu. Ca - percent	6.1	6.4	6.7	5.4	6.9	5.9	7.5	5.9
pH - of paste	8.0	8.0	8.0	8.1	8.1	8.1	8.1	8.1
ESP - percent	21.5	24.3	24.3	26.4	31.4	21.5	24.3	26.4
Second Foot								
EC_S - mmhos/cm	3.0	4.3	3.8	4.8	6.3	7.4	10.0	8.0
Solu. Ca - percent	7.5	5.1	5.5	5.5	7.5	5.4	7.2	5.5
pH - of paste	8.0	8.2	8.2	8.1	8.0	8.1	8.0	8.1
ESP - percent	19.8	24.3	26.4	33.1	26.4	31.4	28.1	38.1
Third Foot								
EC_S - mmhos/cm	-	-	-	-	8.3	6.6	11.7	7.0
Solu. Ca - percent	-	-	-	-	8.0	5.3	8.1	4.8
pH - of paste	-	-	-	-	8.1	8.2	8.1	8.2
ESP - percent	-	-	-	-	26.4	29.7	28.1	34.7

* Sample taken from plot 8, "electro-reclamation". Each determination represents a sample constituted of 6 cores taken at the location indicated.

Significant difference at 0.05 level between samples taken at different distances from the electrodes was not found.

Terms: EC_S = conductivity of saturation extract
ESP = exchangeable sodium percentage

Table 5. The effect of "electro-reclamation" treatment of soil on the yield of sudan grass hay.

PLOT NUMBER	TREATMENT	SUDAN HAY	RANK*
		lbs/0.0003A	
1	None	2.31	6
12	None	2.31	6
3	Electric	2.19	9
5	Electric	2.38	4
8	Electric	2.63	1
10	Electric	2.19	9

L.S.D. 0.05 Not significant as result of electric treatment.

*Rank is defined as placing on basis of 1 being the plot giving the highest yield and 10 the lowest.

Table 6. The amount of electricity and cost used in the "electro-reclamation" equipment.

DATE OF READING	PREVIOUS READING	PRESENT READING	K.W.H. USED	NET COST	CALCULATED COST OF CURRENT
	Watt	Watt	K.W.H.	dollars	decrease/day
4-27-56	0000	0034	340	16.00	2.00
5-29-56	0034	0149	1,150	38.65	1.208
6-28-56	0149	0245	696	33.90	1.130
7-30-56	0245	0332	770	29.15	0.911
8-28-56	0322	0346	240	12.00	0.857

$$\frac{\text{Total charge for current}}{\text{No. of days of operation}} = \$1.118$$

Table 7. The effect of corrosion on the current (DC) flow for each anode.

ANODE POLE NO.	CORRODED	POLISHED (NOT CORRODED)
	amps.	amps.
1	2.89	3.07
3	2.67	2.84
5	2.51	3.18
Average	2.47	3.03

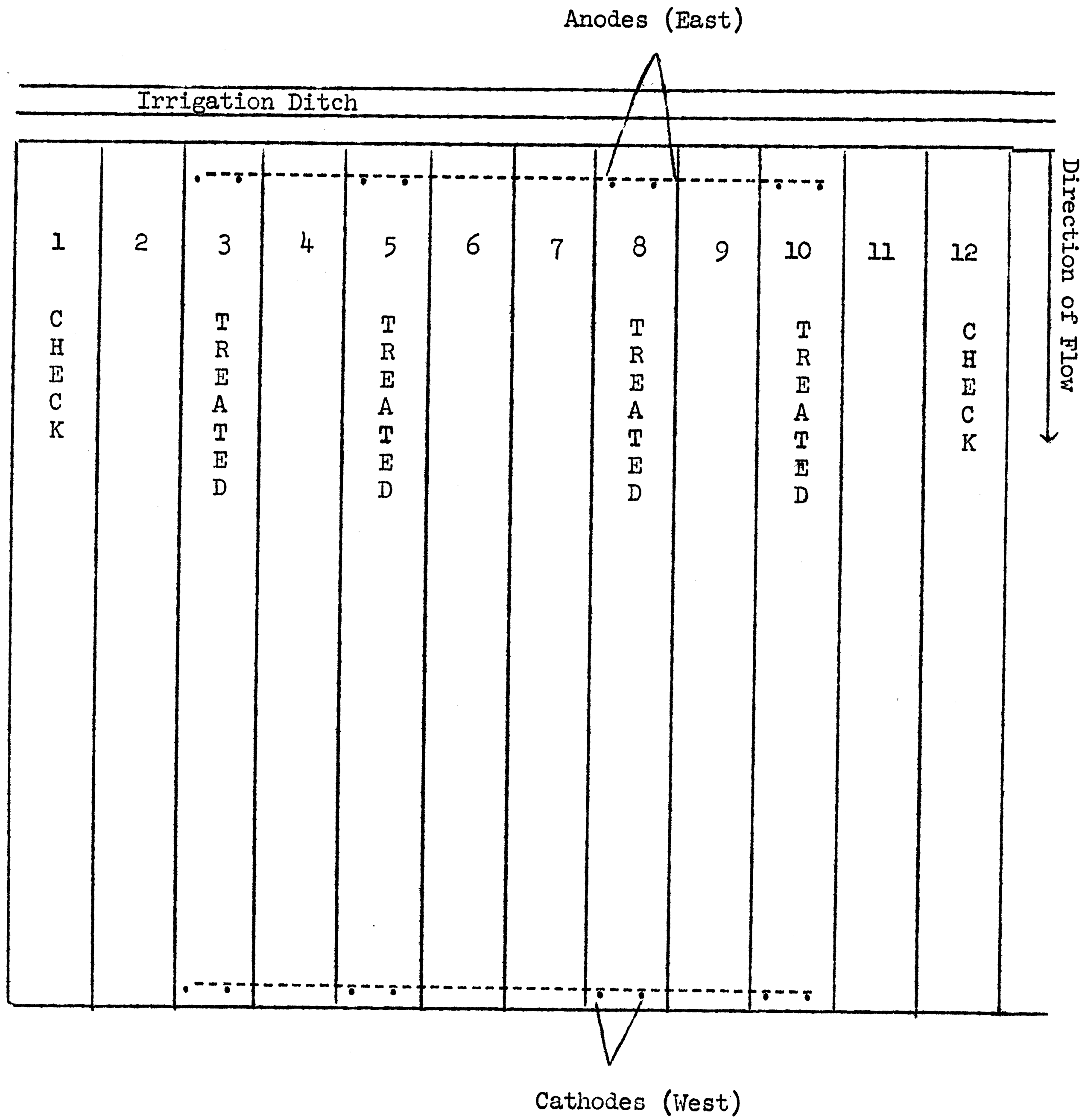
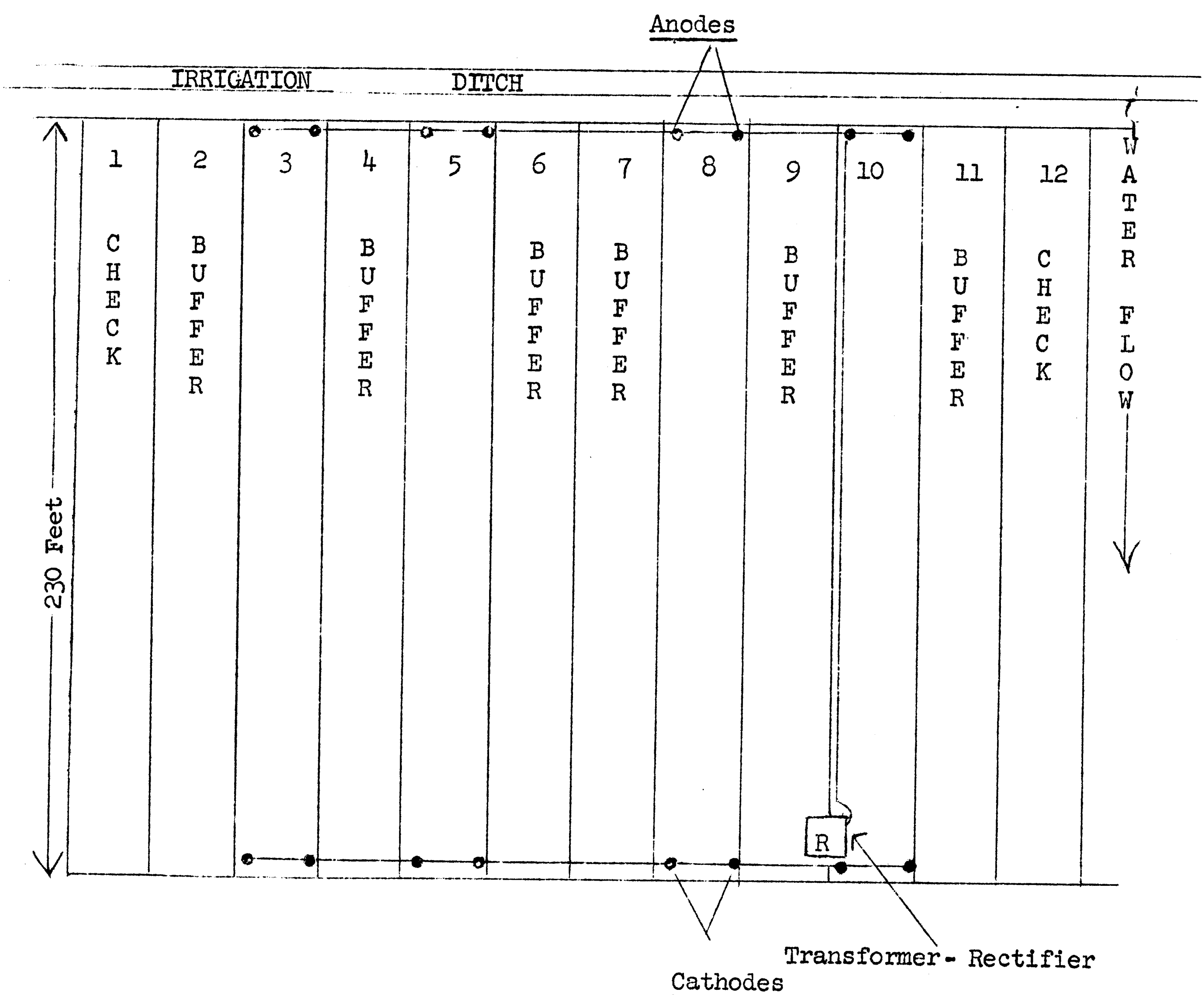


Figure 1. The field plot design of the "electro-reclamation" experiment on the U. of A. farm at Safford.

ELECTRO-RECLAMATION FIELD PLAN



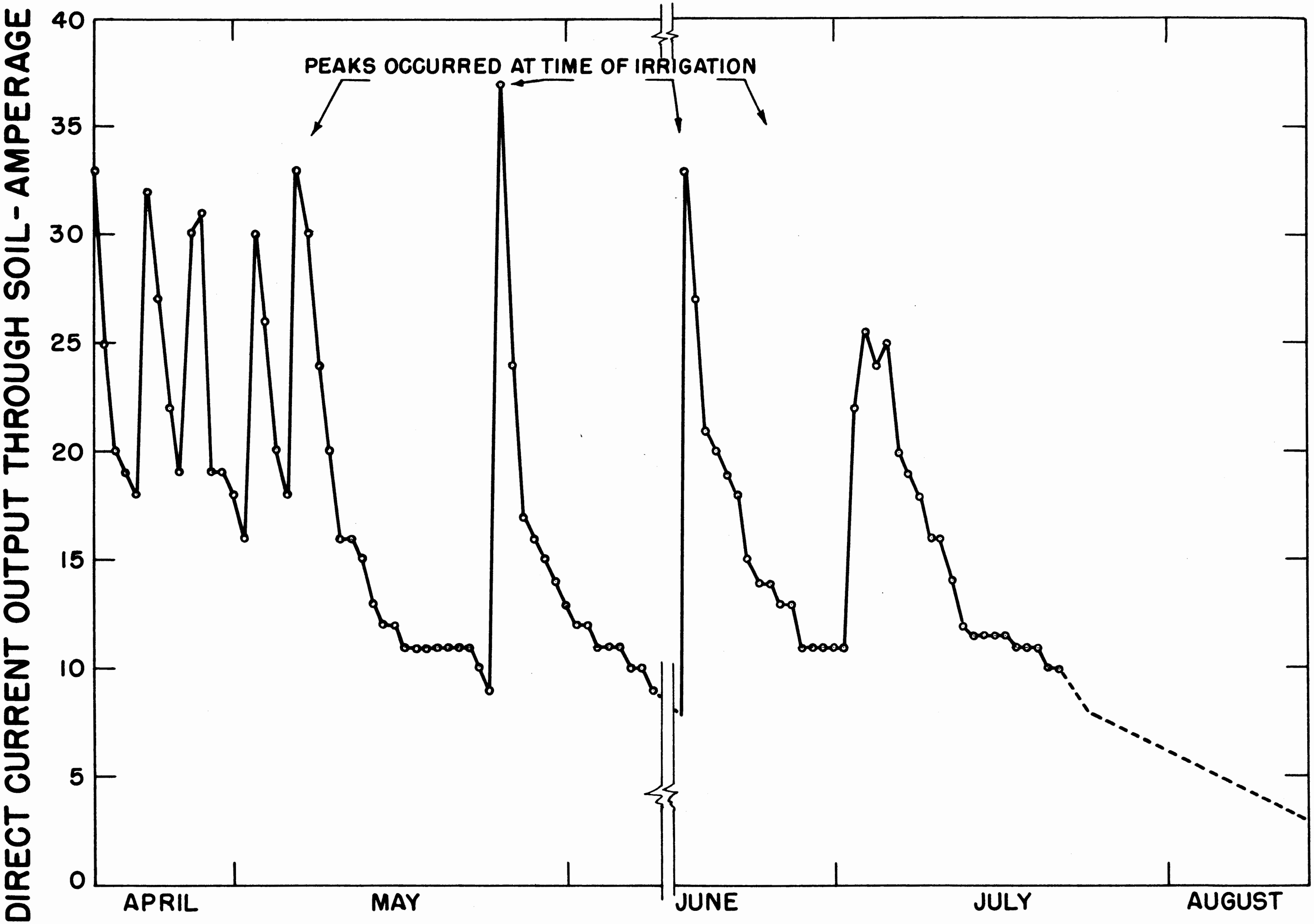


Figure 2.- The amount of direct current flowing into the soil during the time of experimentation. Peak current flow corresponded with a wet soil during time of irrigation. As the soil dried less current flowed through the soil. The area was cropped to Sudan Grass during the time of experimentation.